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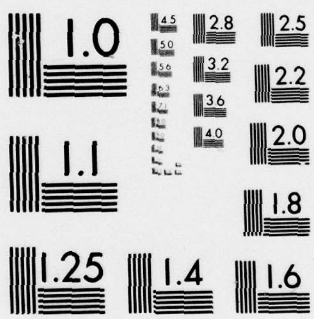

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NAVAL AIR PROPULSION TEST CENTER

TRENTON, NEW JERSEY 08628

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NAPTC-PE-86 MAY 1976

OPERATING CHARACTERISTICS OF A NON-IONIZING ELECTROSTATIC COALESCER/PRECIPITATOR

By: J. Floman

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The latest modification of an electrostatic precipitator was evaluated for its ability to remove water from jet fuel. Satisfactory operation was obtained for water concentration up to 50 ppm with deteriorating performance at higher water concentrations.

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PROPULSION TECHNOLOGY AND PROJECT ENGINEERING DEPARTMENT

NAPTC-PE-86 MAY 1976

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CONVERSION FACTORS: SI TO U.S. CUSTOMARY UNITS

Convert From	To	Multiply by
liters (l)	gallons (gal)	$2.641\ 720 \times 10^{-1}$
liters per second (l/s)	gallons per minute (gpm)	15.850 320
pascals (Pa)	pounds per square inch (psi)	$1.450\ 377 \times 10^{-4}$
millimeters (mm)	inches (in)	$3.937\ 008 \times 10^{-2}$

INTRODUCTION

The Naval Air Propulsion Test Center (NAPTC) was authorized by the Ground Support Equipment Department (GSED), Project Number GSE 74-2323, reference 1, to evaluate a non-ionizing electrostatic coalescer/precipitator (Electro-Filter) for aircraft fuel. Similar filters are presently being used to reclaim insulating oil in the electrical power industry. A previous program (reference 2) was undertaken to evaluate the feasibility of using an electrostatic filter in removing water from aircraft fuels. Deficiencies found during this initial testing resulted in the redesign of the unit by the manufacturer. The new design incorporated changes which were intended to ease the operation and improve the water removal ability of the Electro-Filter.

The advantages of an electronic filtering device would be low maintenance due to the lack of filtering media, little or no pressure differential across the filter, ease of operation and the ability to constantly monitor the quality of the fuel in a system.

CONCLUSIONS

1. The Electro-Filter was able to remove all of the free water from fuel having a concentration of 50 parts per million (ppm) of free water. As the water concentration was increased above 50 ppm, the water removing ability of the filter deteriorated.

2. Pressure differential across the filter housing was low for all water concentrations up to 500 ppm (did not exceed 2.1×10^4 Pa (3 psi)).

3. The housing was well constructed and provided easy access to electrical components. The safety precautions taken to insure that the filter was insulated from sparking seemed to be adequate.

4. Arcing and short circuits were not experienced when adding 50 ppm of water to the fuel. At 100 ppm water concentration, the grid system sustained a short circuit and the fuses blew, causing deactivation of the filter.

5. The current and voltage readings fluctuated but there was an apparent correlation between the grid potential and free water in the fuel.

RECOMMENDATIONS

1. The results of this program do not warrant an effort to replace conventional filtration systems by electro-filtration at this time, but the potential advantages, along with indications that the principle is feasible, suggest that a minimum effort should be maintained to follow the state-of-the-art of electro-filtration for possible future applications.

2. If future improved versions of the electro-filter are designed, greater attention should be paid to safety and convenience features, as discussed in this report.

DESCRIPTION

1. The non-ionizing electrostatic coalescer precipitator was manufactured by Electro-Filter Systems Division of International Plasma Corporation, Hayward, California as Model 616. It requires a grounded power source of 110 volts, 60 hertz and 16 amperes. The other connections required are for the fuel inlet and outlet connections and provision to drain excess water from the filter. The manufacturer states that the minimum flow rate is 1.9 l/sec (30 gpm) at a maximum inlet gage pressure of 3.1×10^5 Pa (45 psi), for continuous service. The filtering unit is composed of three subassemblies; a housing or vessel which contains the grids and through which the fuel flows; the grid system which performs the contamination removal process; and the power supply and electronics section.

2. The housing is a horizontal cylinder, 406 mm (16 in) in diameter and 1520 mm (60 in) long. The ends of the vessel are sealed by belled caps fastened by Marman clamps. Drain bosses are welded to the bottom of the housing. The fuel inlet is from the rear of the vessel and the outlet is on the top at the end farthest from the inlet. A sight glass is provided on the outlet. Two automatic air bleed valves are located on top of the housing. These valves allow the air inside the vessel to escape as the fuel enters and also remove air which might enter the system during operation. A float valve is located on the vessel top near the inlet. The float is housed within a glass tube and actuates a switch only after the housing is filled with fuel. The filter cannot be electronically started until the float rises. This insures the absence of air (thereby removing a possible explosive air-fuel atmosphere) within the vessel before the actuation of the electronic systems.

3. Figure 1 is a photograph of the grid system. The system consists of a series of evenly spaced triangular shaped elements. These elements are joined at the bases forming a sawtooth strip. The first stage of the grid structure contains nine strips in eleven rows with the bases of the triangles facing alternately upstream and downstream. Every other strip is riveted to a teflon coated aluminum rod which passes parallel to the plane of each strip, at the top and bottom. A third solid plastic rod is placed between the teflon rods in order to provide more rigidity to the assembly. The teflon coated rods serve as the electrical path for the current. Each alternate grid strip in each plane is of opposite electrical polarity to the next strip. As all the planes are parallel to the flow stream, there is a minimum resistance to flow.

4. The second stage of the grid system contains eight strips in ten rows and the third stage has three strips in ten rows. Each section of the grid structure is separated from the adjacent section by a

teflon coated screen mounted between the grid stages. There is also a screen at the fuel outlet port. This prevents the passage of large solid contamination and water drops that might have been separated from the fuel stream, but which would not have had time to settle into the bottom of the vessel.

5. The electronics of the Electro-Filter are located in an explosion proof housing on top of the vessel. The wiring from the grid system is sheathed in stainless steel tubing with suitable connectors. The top plate of the housing, meter openings and switches are gasket sealed. All bolts and screws are o-ring sealed. The power supplies are located inside the instrument housing. The first stage supply is rated at 5 kilovolts (KV), 10 amperes, regulated direct current. The voltage range is adjustable from 1.3 to 5.0 KV. The adjustment knob for this supply, as well as those for the stage 2 and 3 supplies are located, somewhat inconveniently, on the side of the instrument housing, below the grid wire sheathings. Stage 2 and 3 power supplies are adjustable from 1 to 6 KV. Each stage is controlled by an electronic regulator that limits the output current to 0.1 ampere at stage 1 and 30 milliamperes at stages 2 and 3. The input current to each supply is limited to 3 amperes. The primary and secondary circuits are completely isolated by using transformers. A current limiting circuit uses an optical coupling device to preserve the isolation. Three lights are mounted on the top panel and are used to indicate the operation of the electronics of each grid stage. In addition, the voltage and current draw of each grid stage is monitored by using a rotory switch to indicate each of the individual stages, on a voltmeter and ammeter located on top of the housing.

6. Each of the high voltage power supplies is split with respect to ground. Therefore approximately half of the output voltage is above the chassis ground and half is below chassis ground. A switch is provided to allow the measurement of the grid voltage that is applied to each of the three stages, on either side of the chassis ground. This is designated by plus and minus. The total voltage applied to each grid stage is the sum of the plus and minus voltage readings. The external power source required is 110 volts, 60 hertz and 16 amperes. A three wire (grounded) outlet is mandatory for safety reasons.

7. A schematic of the test facility is shown in figure 2. A photograph of the Electro-Filter installed in the facility is shown in figure 3. The test system consists of a fuel tank containing approximately 189 l (50 gal), a centrifugal pump and drive, a clean-up coalescer and a clay filter. Water is injected on the inlet side of the pump by pressurizing a tank. This insures that the pump will emulsify the water before it enters the Electro-Filter. Pressure gages are located before and after the test filter, after the clean-up and after the clay filters. These gages allow the pressure differentials across the test filter, the clean-up unit and clay unit, to be determined. Fuel samples were taken before and after the Electro-Filter by using probes placed in the lines parallel to the lines and facing upstream.

8. The fuel used for the test program conformed to Specification MIL-T-5624J, Grade JP-5. Prior to each test the fuel was circulated through the clay filter, bypassing the test unit. This insured that the fuel was dry (no undissolved water) and did not contain surface active agents (surfactants). The lack of surfactants was determined by a requirement for a Water Separometer Index, Modified (WSIM) of 95 or higher. A high WSIM is generally accepted as being indicative of a fuel with little surfactant present. WSIM tests were conducted in accordance with ASTM Method D2550.

9. The test program was performed using a fuel flow of 0.631 liters per second (10 gpm) and an inlet pressure of 2.1 X 10^5 Pa (30 psi). Water was added in concentrations of 50,100, 250 and 500 ppm of the fuel flow. Any free water remaining in the fuel effluent (after the test unit) was determined using the Aviation Fuel Water Detector Kit and associated pads (Specification MIL-D-81227).

10. Before the grids were installed in the vessel, a "jumper" was placed across the float switch and the main power was actuated. The voltage at stage one was set to approximately 4 KV. The voltages for stages two and three were set to approximately 6 KV. The current was also recorded for each grid stage. The "jumper" was then removed and the grids were installed in the vessel and the end cap replaced. After circulating the fuel through the clay filter, as stated above, the Electro-Filter housing was filled with fuel. The voltage and current were recorded at each of the grid stages. These readings formed the basis for comparing clean fuel with fuel contaminated with water.

DISCUSSION AND ANALYSIS OF RESULTS

1. After installing the Electro-Filter in the test system, preliminary testing was conducted to familiarize the personnel with the filter controls and operating characteristics. When adding water, a defective valve caused a large quantity (estimated at three percent) of water to be added to the fuel. Arcing was immediately evident by "popping" sounds coming from the vessel. The fuse on stage one also "blew". The main power was turned off and the fuel was circulated through the test unit and the clean-up coalescer. It was hoped that this circulation would cleanse the grids of water. The fuse was replaced and the filter was activated when free water was no longer present in the fuel. The current readings for stages two and three were fluctuating but the voltage seemed stable. Water was injected into the fuel at a rate of 50 ppm. The effluent fuel had zero ppm. This condition was maintained for one hour. The water injected into the fuel was increased to 100 ppm. Arcing was immediately heard and the stage one fuse again blew. The water was turned off and the fuel allowed to circulate through the unit for approximately five minutes while the fuse was replaced. The filter power was activated and the stage one fuse again blew. The filter was drained and the grids were removed. Upon inspection, it was evident

that a carbon path was formed from a metal grid element, along the plastic support rods, to a contact in the vessel housing. It was also determined that this path was caused by water drops rolling along the plastic frame which holds the teflon screen in place. The carbon tracks were removed by filing and using a solvent. A strip of fuel resistant rubber was installed on the edges of the screen housing to direct the water away from the plastic rails.

2. The arcing mentioned above was experienced in various phases of the testing program. When the system is arcing, a "popping" sound is heard coming from the filter vessel. Large fluctuations are noticed on the volt meter. Throughout the testing, the arcing was never violent nor did it persist for long periods of time. When arcing was persistent, a fuse would blow, usually on stage one. Arcing is caused by air or water bubbles in the fuel providing a high conductivity path between adjacent grid elements.

3. The pressure differential throughout the testing sequence was never more than 2.1×10^4 Pa (3 psi). This low pressure drop was due to the lack of restriction to the flow by the Electro-Filter components. The grid structure, by placing the metal elements parallel to the stream, reduces the pressure drop through the vessel. The only other resistance to the flow is the teflon screen but this also would be minimal.

4. Figure 4 shows the results of the performance tests. No water was recorded in the fuel effluent at the 50 ppm water concentration. The water in the effluent then increased as the influent water concentration increased. When 500 ppm of water was added to the fuel, 30 ppm of water was present in the effluent. No arcing was noted at the 500 ppm concentrations.

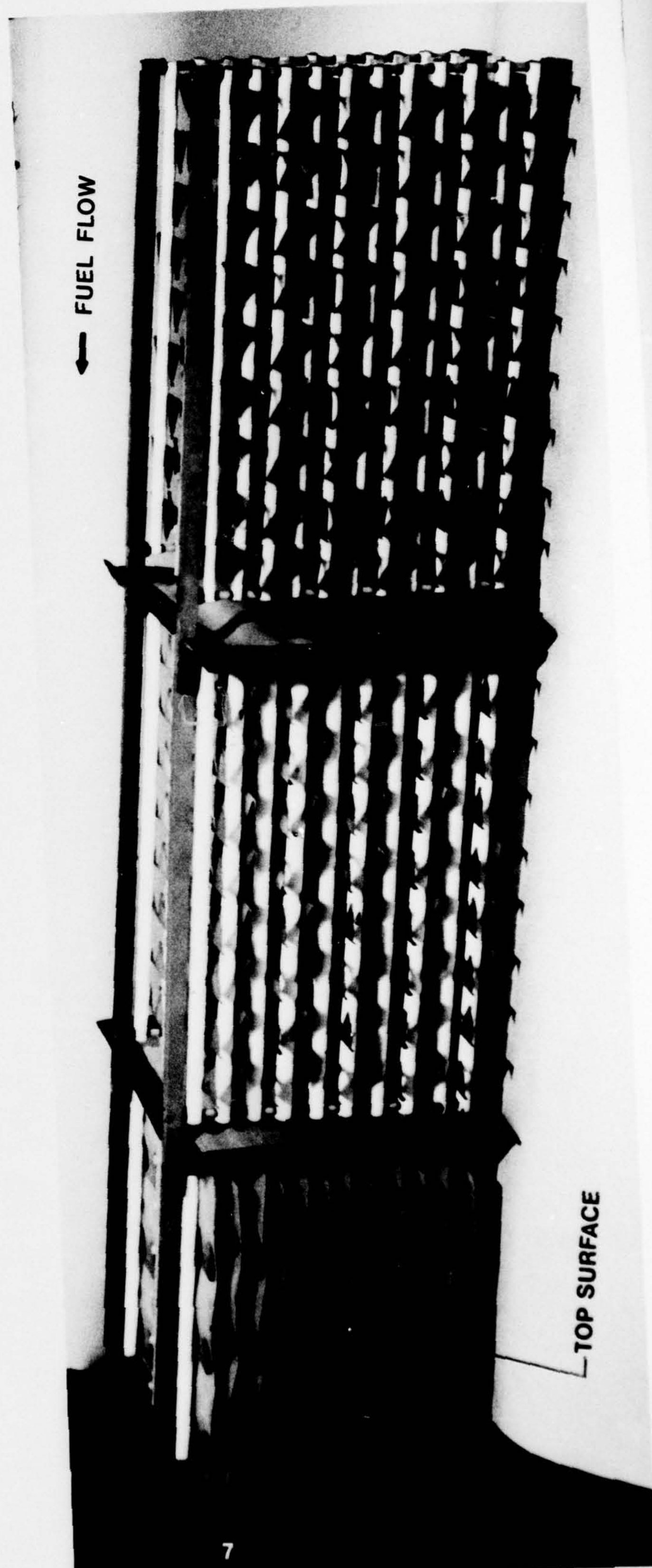
5. Figure 5 shows the relationship between the influent water concentration and the potential across the grids. The grid potential shown is the sum of the plus and minus potentials, in kilovolts. This compensates for the design of the electrical system whereby approximately half of the voltage of the grids is above ground and half is below ground. In order to compensate for differences in the starting potentials, the voltage value obtained at the start of each test, using clean dry fuel, was subtracted from the values indicated at the various water concentrations. This practice allows for a correlation to be made between tests without regard to the starting meter readings.

6. The grid potential increased as the water concentration increased up to 100 ppm. Thereafter the potential decreased as more water was added. This trend is evident for stages one and three. At stage two, the potential increased to the 250 ppm water concentration and decreased at 500 ppm. A possible explanation for this trend is that the grids were overloaded and shorted to ground as the water concentrations were increased. Also evident is the difference between the grid stages in potential readings. The higher potential at stage one indicated that most of the water is being removed by this stage. Indications are that

stage three removes considerably less water than stage one and therefore stage three might be eliminated without effecting the performance of the filter.

7. Toward the end of the testing sequence, the voltage and current readings were fluctuating. Attempts to regulate these fluctuations by decreasing the potential across the grids were not successful. Clean fuel was circulated through the system for eight hours in an attempt to clean the grids but the fluctuations were still present. Upon inspecting the grids, a grayish powder was observed on the grid elements. Attempts to dissolve the powder with alcohol were not successful. As the deposit was very thin, a sample could not be obtained for a laboratory analysis.

FIGURE 1.
ELECTRO FILTER
GRID SYSTEM



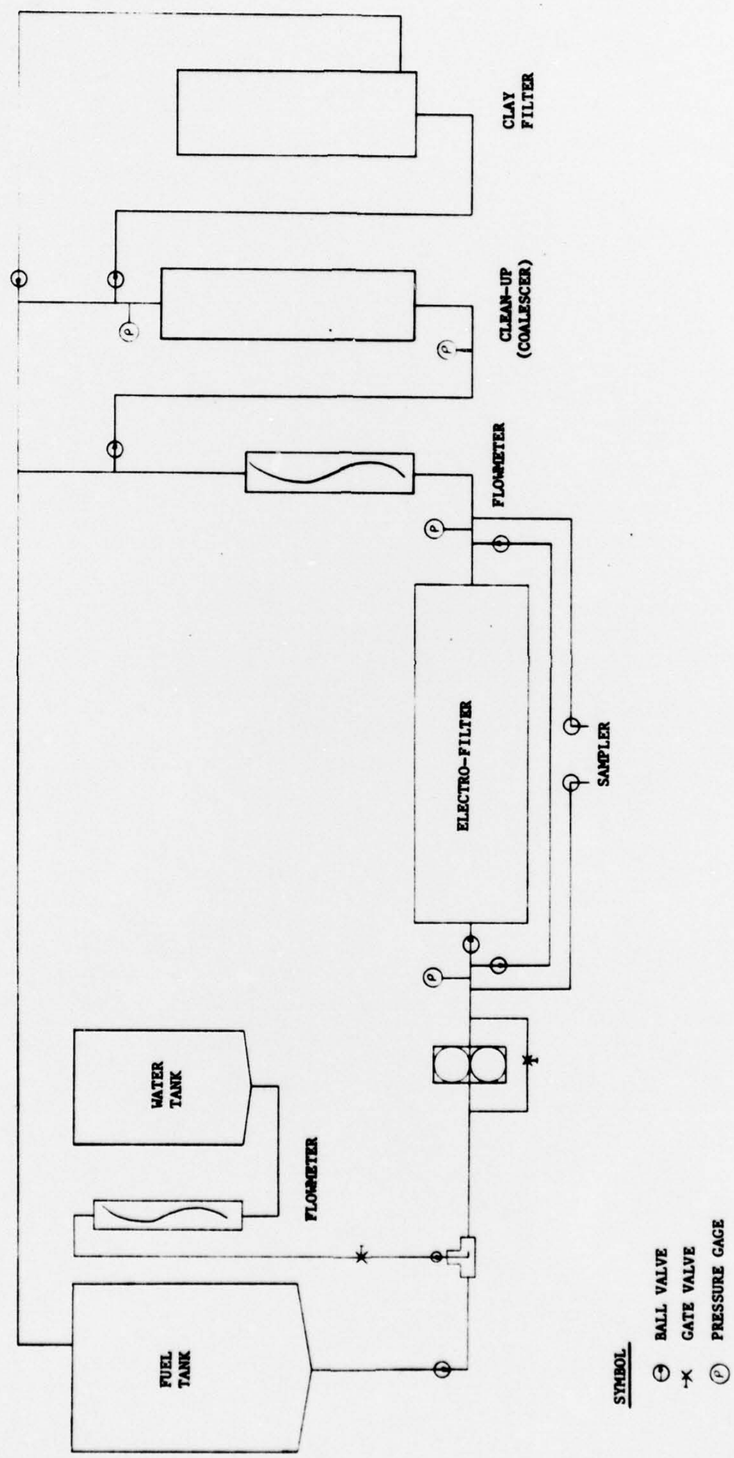


FIGURE 2. ELECTRO-FILTER TEST SET-UP

FIGURE 3. ELECTRO FILTER NON-IONIZING ELECTROSTATIC COALESCER PRECIPITATOR AND TEST FACILITY

FIGURE 4. ABILITY OF ELECTRO-FILTER TO REMOVE VARIOUS QUANTITIES OF FREE WATER FROM JP-5 FUEL

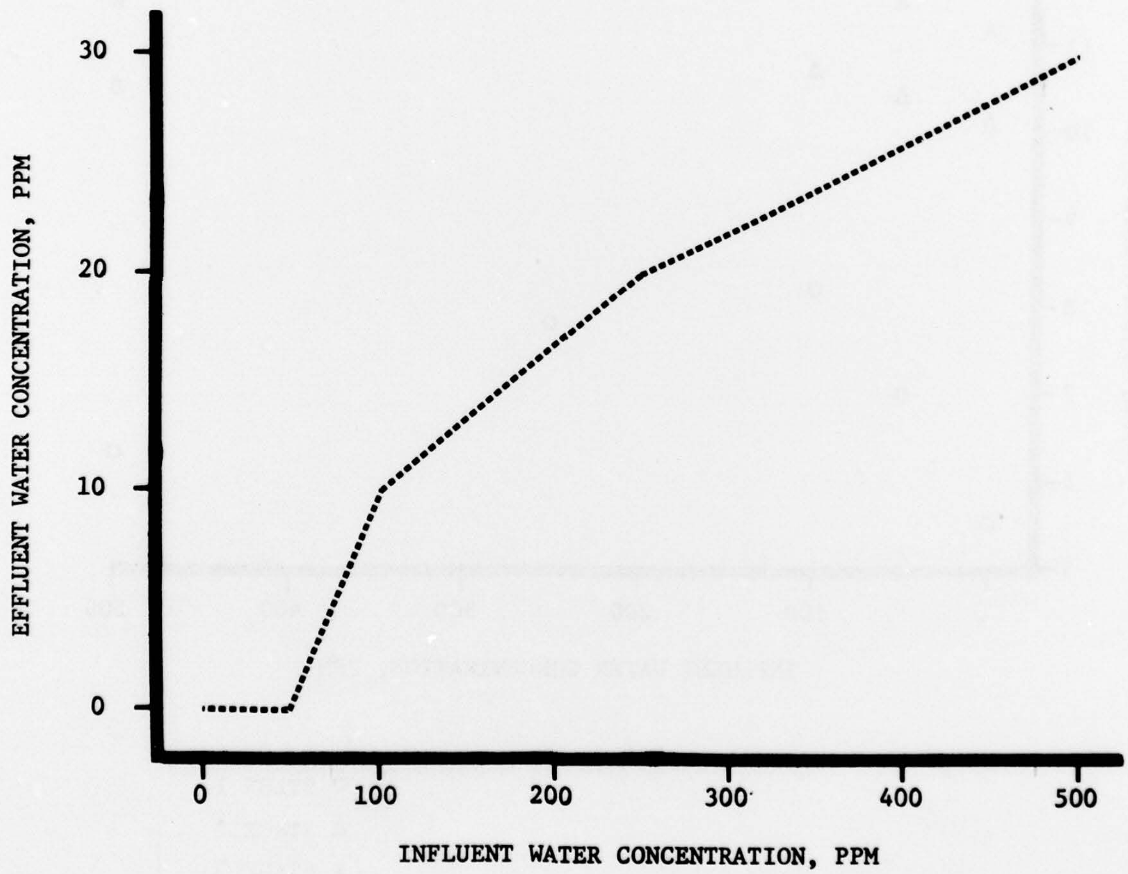
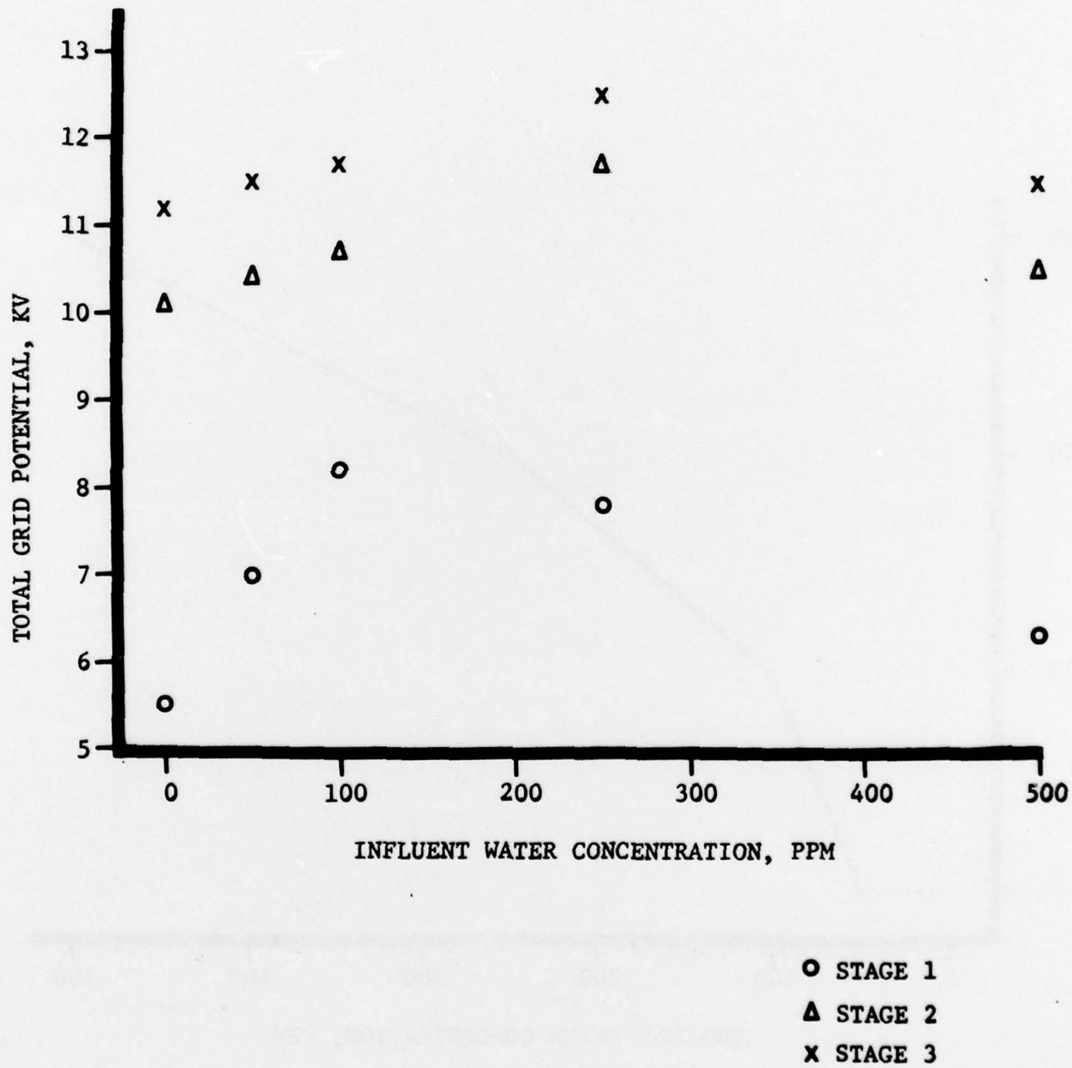


FIGURE 5. GRID POTENTIAL VERSUS INFLUENT WATER CONCENTRATION AT EACH GRID STAGE



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